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**THE INFLUENCE OF COVER STRIPS
ON THE DISTRIBUTION AND
ACTIVITY PATTERNS OF
Macrobrachium rosenbergii**

Report No 86-267-K

G.L. Vascotto
Senior Research Scientist
Chemical Research Department

ABSTRACT

The responses of Macrobrachium rosenbergii to the presence and absence of artificial cover strips in four different configurations were studied in four aquaria. The animals displayed a strong preference for the cover strips. When strips dangling from the surface were presented, the animals could be induced to occupy the upper half of the water column at densities four times higher than in a bare tank. Presence of cover strips also substantially reduced the level of activity in the aquaria.

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EXECUTIVE SUMMARY

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If prawns are to be raised in intensive thermal aquaculture schemes, techniques will have to be developed for maximal utilization of the warm water volume available. The prawns are typically bottom living animals, and this study attempted to determine whether they can be induced to occupy the water column when artificial substrates are provided in an aquarium setting.

While the results confirmed that these animals have a strong preference for the bottom where on the average 90 per cent resided during the study, the presence of surface strips resulted in 60 per cent of younger animals and 40 per cent of the older animals moving to the upper half of the water. It was also found that the presence of cover strips significantly reduced the amount of movement of the animals in the aquaria.

The results of this study suggest that the use of cover as a means of increasing the standing stock warrants serious consideration and further research, particularly if mature individuals can also be induced to occupy the cover supplied. The reduction in activity of the animals in the presence of cover is also interesting since it may have an impact on the number of aggressive encounters and ultimately have a positive influence on survival.

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ontario hydro research division

TO: Dr. D. Mills
Director of Research

THE INFLUENCE OF COVER STRIPS ON THE DISTRIBUTION AND ACTIVITY PATTERNS OF *Macrobrachium rosenbergii*

INTRODUCTION

Late in 1984 the Biological Research Section identified the Malaysian prawn *Macrobrachium rosenbergii* as a species having high potential for thermal aquaculture schemes (Ontario Hydro Research Division Report No 84-56-K). The projected high yields and market values, its large size, its rapid growth, the fact that for the growth phase it requires warm fresh water, and the fact that it already is commercially grown at warmer latitudes, all were taken as positive indicators. On the basis of these indicators it was decided to carry out a series of investigations to determine the feasibility of raising these prawns in Ontario with warm water supplied by Ontario Hydro's generating facilities.

The Malaysian prawn is widely grown under such names as giant prawn, giant freshwater prawn, giant Malaysian prawn, and freshwater prawn. The commercial methods of raising prawns in North American and the Middle East are through "extensive" aquaculture techniques; that is, the prawns are raised in shallow, bare, naturally heated, earthen ponds with a minimum of management, although supplementary feeds are provided. Yields of 3000 kg/ha are not uncommon. However, higher yields should be attainable in "intensive" culture techniques.

In Canada, early investigations of the feasibility of raising Malaysian prawns by the federal government at the Inwood Hatchery and the Ontario government at Guelph University, both concluded that extremely high mortality due to cannibalism precluded the serious consideration of the animal for aquaculture. Indeed our early experiences tended to support the government conclusions; in our first year, survival and growth were discouraging (Ontario Hydro Research Division Report No 84-457-K). However, it was subsequently shown that the sources of the problem were a poor diet (Ontario Hydro Research Division Report No 85-192-K) and the antiseptic conditions under which the animals were maintained (Ontario Hydro Research Division Report in preparation). At present, both good survival and growth are being attained.

Studies currently under way are concentrating on the development of the technology for "intensive" growth (ie, high density of animals per unit volume of water), and to grow animals to a consistent large size by eliminating or reducing the heterogeneous individual growth (HIG) phenomenon. The HIG phenomenon is considered as "the single most constraint to successful rapid domestication" of this species (Malecha et al, 1980).

In previous studies Smith and Sandifer (1975) found that the addition of cover in experimental situations enhance the survival of prawns in the postlarval and juvenile stages. In fact, some of the commercial growers in Hawaii place frames of synthetic webbing into their nursery ponds to enhance survival. Cohen et al (1983) and Ra'anan et al (1984) concluded from their research in Israel that providing additional cover in growout ponds may increase the yield of Macrobrachium. The best yield that they obtained was comparable to the high yield reported for Taiwanese farms which don't use cover but emphasize the control of the water quality.

We postulated that the low production achieved by commercial growers may be partly due to the limited substrate available for animals to colonize in the bare earthen ponds where the prawns typically tend to use only the bottom.

This study was designed to provide some basic information which might form the basis for designing studies which will lead to the development of "intensive" culture criteria, and attempted to determine whether the natural distribution and activity patterns of the animals could be altered to elicit use of the upper portions of the water column by animals of the four to six month age range by providing artificial surfaces. The assumption was made that if greater use of the water column could be induced then it may be possible to increase the stocking density. In support of the above goal, the following objectives were set.

- determine the 'normal' diurnal distribution and activity patterns of the prawns and how they varied with age;
- determine whether the normal distribution and activity patterns could be manipulated by varying the configuration of the cover presented;
- determine if the animals displayed a preference for horizontal or oblique surfaces.

MATERIALS AND METHODS

Experimental Design

Ten-week old post-larval prawns obtained from Amoriant Farms in Hawaii, and reared in communal tanks to four months of age, were used for this study.

The experimental layout consisted of four 180 L rectangular glass tanks (46 cm H x 43 cm W x 99 cm L), each representing a treatment; the tanks were not replicated. Each tank was exposed to a diurnal light cycle of 7 hours of daylight (at 4.5 to 5.5 lux) and 13 hours of darkness (0.4 to 0.6 lux); at dawn and dusk lights were dimmed over a two-hour period (1.5 to 2.5 lux). Aeration was provided by an air stone which was relocated weekly to reduce possible bias. Heated dechlorinated water was provided to the tanks by means of a flow-through system and the in-tank temperatures were maintained between 28° and 30°C.

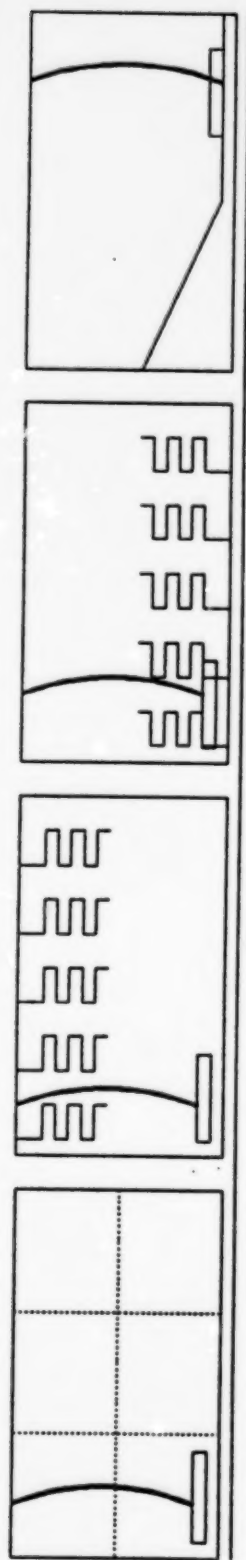
To emulate cover strips of flat PVC material (45 cm L and 6 cm W) were bent into compressed sinusoidal strips (roughly two cycles) having a total overall length of approximately 20 cm.

One tank was maintained without additional material (bare), other than the air stone and tube, and was used to emulate conditions in commercial ponds. A second tank was provided with eight equally spaced cover strips suspended from the surface and was used to test the degree to which animals could be induced to use the upper half of the water column. A third tank was provided with eight cover strips sitting on the bottom to simulate bottom cover and to test the selectivity for cover. A fourth tank was kept bare but half of the bottom was kept level and half sloped upward by 15 cm; this configuration was used to test whether a preference for horizontal or oblique surface existed. A graphic display of the layout of the tanks is shown in Figure 1a-d.

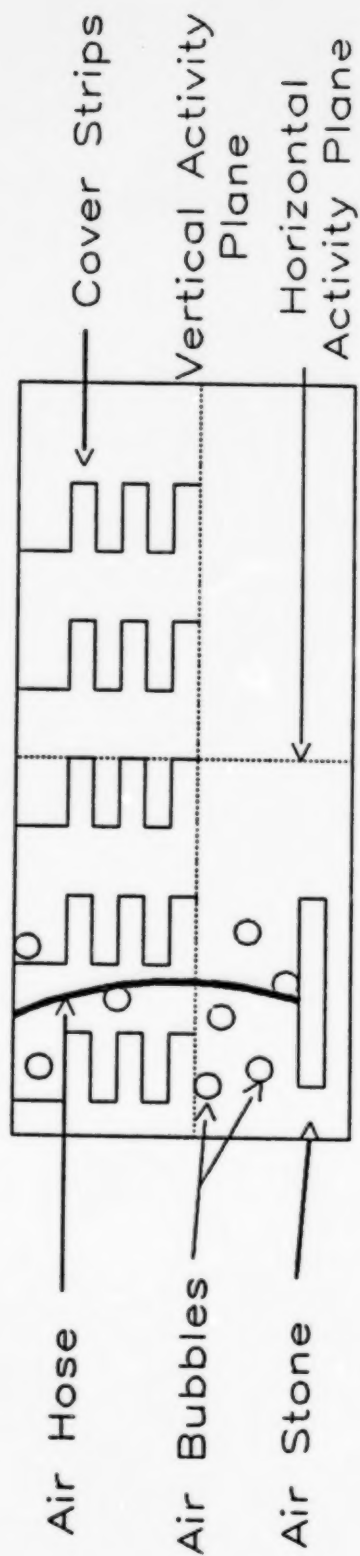
At the start of the study 15 randomly selected animals between 1.35 and 7 gm in weight were placed in each of the four tanks. As the animals died they were replaced once a week from the nursery tanks. Half way through the study all the animals were replaced due to heating system failure.

The animals were fed once a day, and feeding times were alternated weekly between the hours of 07:30 and 10:30.

The study was carried out over a seven-week period. During each week each tank was monitored over one 24-hour period. The data for the third sampling week was discarded due to malfunctions of the heating system, hence six one-week sampling periods of useful data were available from the study. Data on activity and distribution were gathered by a low light level Panasonic video recorder. The activities of the prawn were monitored between the hours of 08:00 to 10:00, 11:00 to 13:00, 16:30 to 18:30 and 23:30 to 01:30; these times corresponding to the light intensities described for dawn, noon, dusk and midnight. Each tank was monitored for one day per week, during which the tanks were isolated by means of opaque canopies. The animals were allowed to settle down for 30 minutes following the setting up of the camera prior to initiating the recording sessions. Data on distribution were gathered from the recordings by dividing the tanks into sixths (see Figure 1a) and counting the animals within each compartment at 15-minute intervals.



A. Bare Tank B. Surface Strips C. Bottom Strips D. Sloped Bottom



E. Detailed Drawing of Surface Strips Aquarium

FIGURE 1

A-D SCHEMATIC REPRESENTATION OF TANKS USED, DOTTED LINES IN A. ILLUSTRATE THE PARTITIONING OF THE TANKS INTO SIXTHS. E. GIVES A DETAILED REPRESENTATION OF A TANK WITH ACTIVITY PLANES SHOWN.

Information on activity was gathered by counting the number of animals crossing an imaginary horizontal and vertical plane over a one-minute period at 15-minute intervals (Figure 1e). These counts represented the repeated measures.

Statistical Treatment

The distribution data were expressed as per cent of the animals found in specific portions of the tanks. It was determined, using the Taylor power law, that the log transformation was the most appropriate transformation, and it was used for the analysis of variance and covariance procedures. The count data for the activity portion of the study were adjusted to 15 animals per tank and also log transformed.

For test of the difference of within treatment means the analysis of variance procedure for balanced designs and the t-test for two sample analysis in STSC STATGRAPHICS were used. For exploratory descriptive data analysis the notch-and-whisker plot procedure in STATGRAPHICS was used. This procedure is a modification of the box-and-whisker plot (McGill *et al.*, 1978). A notch added to the box corresponds to the width of a 95 per cent confidence interval for the median; this allows pairwise comparisons at the 95 per cent level by examining whether two notches overlap.

Since the treatments were not replicated the general mixed model ANOVA from the BMDPC procedure which allows both repeated measures and covariates was used. The procedure uses the maximum likelihood and restricted maximum likelihood approaches to the fixed and random coefficient model. The model used to test the horizontal and vertical activity and distribution consisted of the treatments and period of the day being fixed, with absolute time, time since feeding, and age as covariates.

RESULTS

Distribution and Activity of Prawns in Bare Tank

In the bare tank the prawns exhibited a decidedly epibenthic distribution, with an average of 88 per cent of the animals on the bottom half of the tank, and most of these being in direct contact with the bottom of the tank. For four of the six sampling weeks more than 90 per cent of the animals were found at or near the bottom. In week two, however, a significant number of the animals was found in the upper half of the water column, mean = 30.5% (median = 28%, Figure 2), the higher numbers near the surface were due to animals clinging to the air hose, which on this particular set was located in the middle of the tank.

The influence of the location of the air stone and associated hose on the distribution of the prawns within the tank was investigated by dividing the tank into thirds and comparing prawn densities with different hose locations. In all cases the portion of the tank with

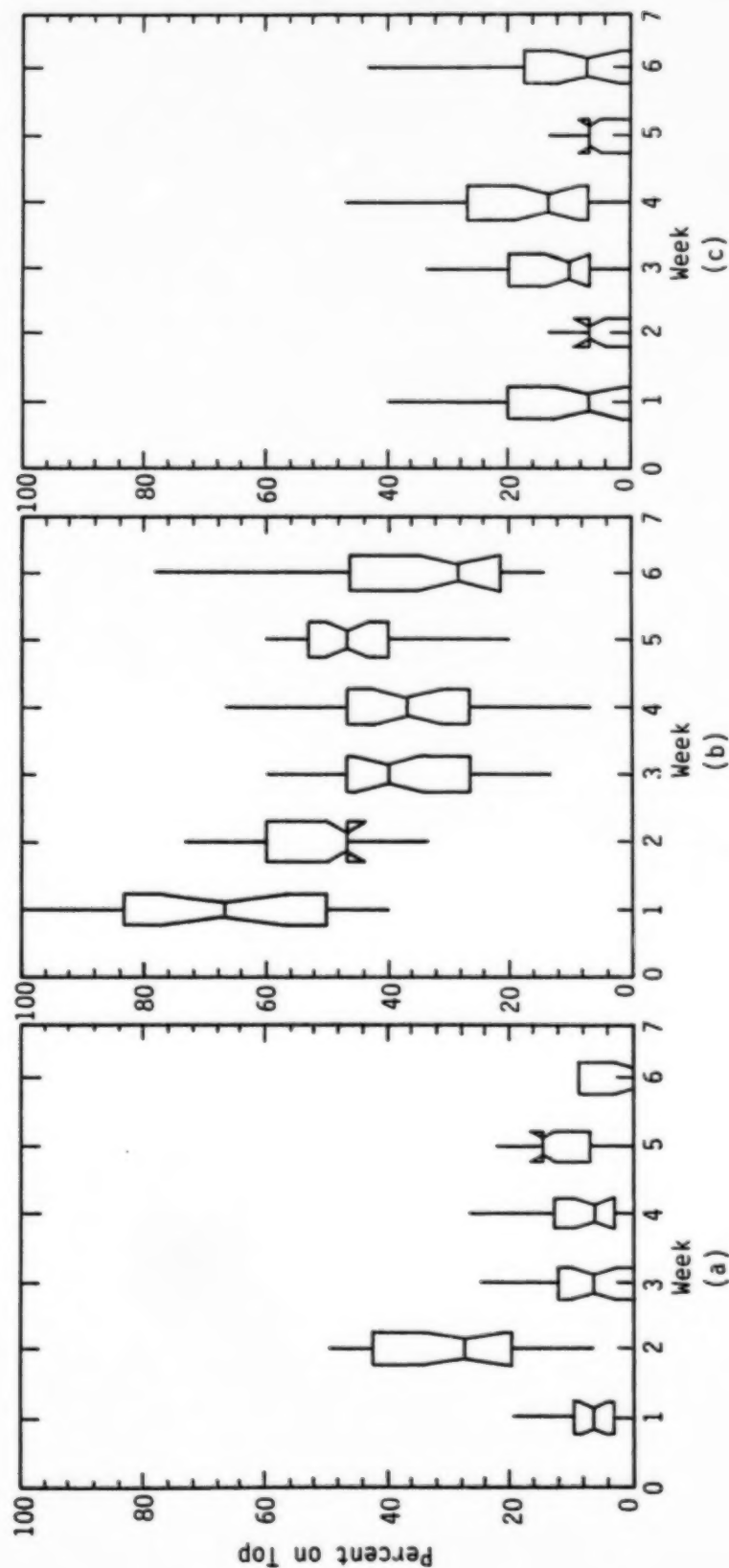


FIGURE 2

PERCENT OF PRAWNS FOUND IN TOP HALF OF WATER COLUMN IN AQUARIA WITH
a) BARE SURFACE STRIPS b) BOTTOM STRIPS OVER SAMPLING PERIOD
CONFIDENCE LEVEL ON THE NOTCHES IS SET TO ALLOW PAIRWISE COMPARISONS TO
BE PERFORMED AT THE 95% LEVEL BY EXAMINING WHETHER TWO NOTCHES OVERLAP.
SITUATIONS WHERE THE NOTCH EXTENDS BEYOND A QUARTILE SHOW A FOLDING
IN BEHAVIOUR AND LITTLE CONFIDENCE SHOULD BE PLACED IN THESE BOXES.

the air stone had the highest mean densities (Table 1), but the differences were not statistically significant at the 95 per cent level.

TABLE 1

Aquarium Third	Hose Location		
	Left	Middle	Right
Left	40.08 (10.9)	29.4 (10.2)	31.3 (9.6)
Middle	31.09 (11.8)	36.6 (8.2)	33.1 (10.1)
Right	28.8 (9.7)	33.9 (8.9)	35.6 (10.9)

Per cent distribution by aquarium thirds of prawns relative to air hose and stone in bare tank. Mean (S.D. shown in parenthesis) shown for 96 trials at each hose location.

The location of the air hose and stone had a significant effect on the vertical distribution of the animals within the tank only when it was located in the center third of the tank (Table 2). The presence of the air stone and hose at the center significantly increased the occupation at all locations of the upper half of the water column.

TABLE 2

Aquarium Third	Hose Location			Mean by Tank Third
	Left	Middle	Right	
Left	2.1 (4.2)	9.0 (7.7)	2.7 (3.3)	4.7
Middle	0.8 (2.2)	11.1 (9.2)	4.5 (7.5)	5.5
Right	3.4 (5.6)	10.4 (5.8)	3.5 (2.3)	5.8
Mean by Hose Location	2.2	10.2	3.6	

Mean per cent of total animals found in the top half of the aquarium relative to the air stone location. Mean (S.D. in parenthesis) shown for 96 trials at each hose location.

No significant diurnal vertical distribution pattern was found (Figure 3). The prawns exhibited a significant diurnal activity pattern in horizontal movement, but none in the vertical. The period of maximum horizontal activity was the dawn period, which was significantly higher than either the dusk and midnight periods which were the lowest (Figure 3).

Comparisons were made in activity at dawn and noon with recently fed as opposed to unfed animals. It was concluded that feeding had no significant influence on the horizontal or vertical activity level (Figure 4).

Activity and Distribution of Prawns in the Sloped Tank

To determine the distribution of the prawns within the sloped tank only observations made at the two extreme thirds of the tank were used, ie, either fully flat bottom or totally sloped. The animals displayed a slight but statistically significant preference for the sloped bottom ($F_{1,382} = 11.219$, $P < .001$). Within the duration of these trials the preference for the sloped bottom did not appear to be age related.

Distribution of Prawns Among Treatments

The general mixed model analysis of variance was used to test whether there was a significant difference in distribution between treatments and time of day. The ANOVA model used is illustrated below:

$$Y = u + a_i + B_j + @B_{ij} + Y_1 \text{age} + Y_2 \text{starvation} + Y_3 \text{time} + Y_4 \text{time} * \text{period} + E$$

a_i = treatment

B_j = period of the day

Age = week sampled

Starvation = time-of-day feeding time

Time = absolute time

The null hypothesis was rejected at the 99% level (Chi-square = 342.17, $P < .0001$). The treatment effects were highly significant. The estimated distribution of the means are shown in Figure 5. The mean percent of animals estimated to be using the upper half of the column in the treatment with surface strips was 43.6% of the animals, while in the other three treatments the estimated means ranged from 4.0 to 7.2% with standard deviations of less than 2%. The time of day was significant as there was a significant treatment*time of day interaction in the surface strips treatment and in the bottom strip treatment. In both cases the animals increased their residence on surface strips during the midnight period. The age of the animals (ie, sampling cycle), time since last feeding, and absolute time on a 24 hour clock were all not significant.

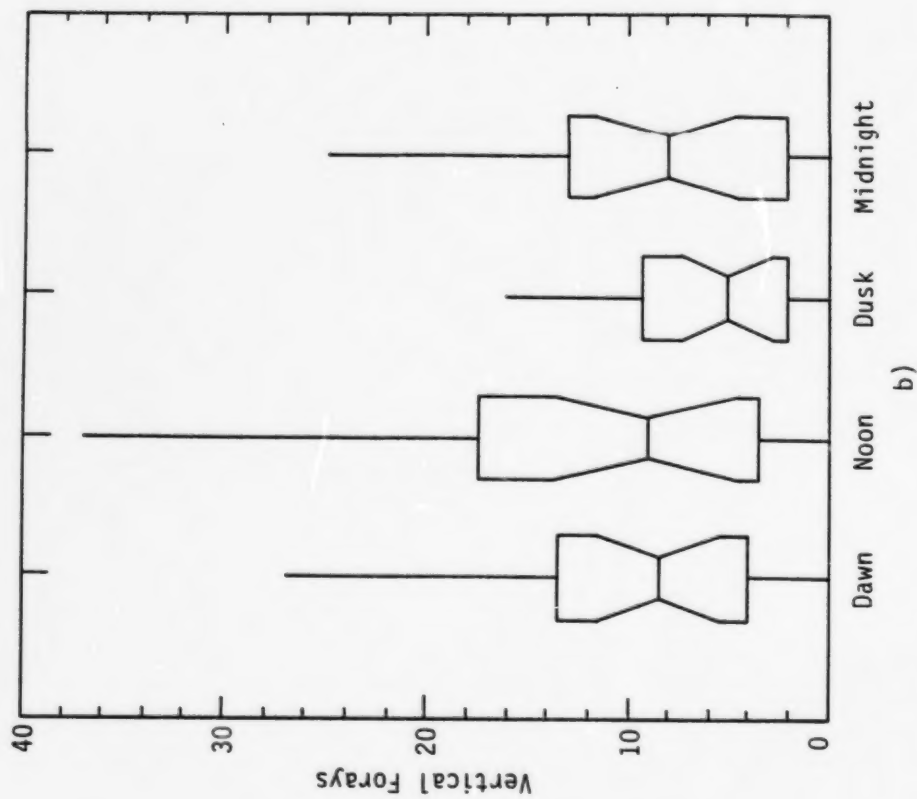
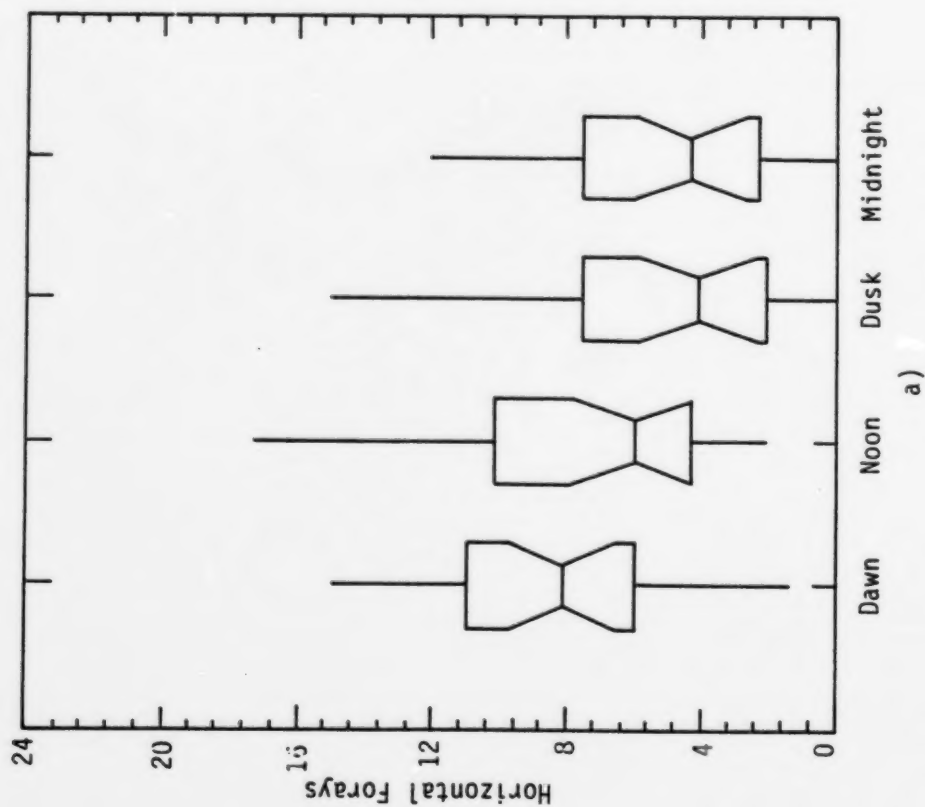


FIGURE 3
ACTIVITY OF PRAWNS IN THE BARE AQUARIUM BASED ON
MEAN NUMBER OF FORAYS PER MINUTE CROSSING
a) VERTICAL AND b) HORIZONTAL PLANES
(UNCORRECTED FOR DISTANCE OR AREA)

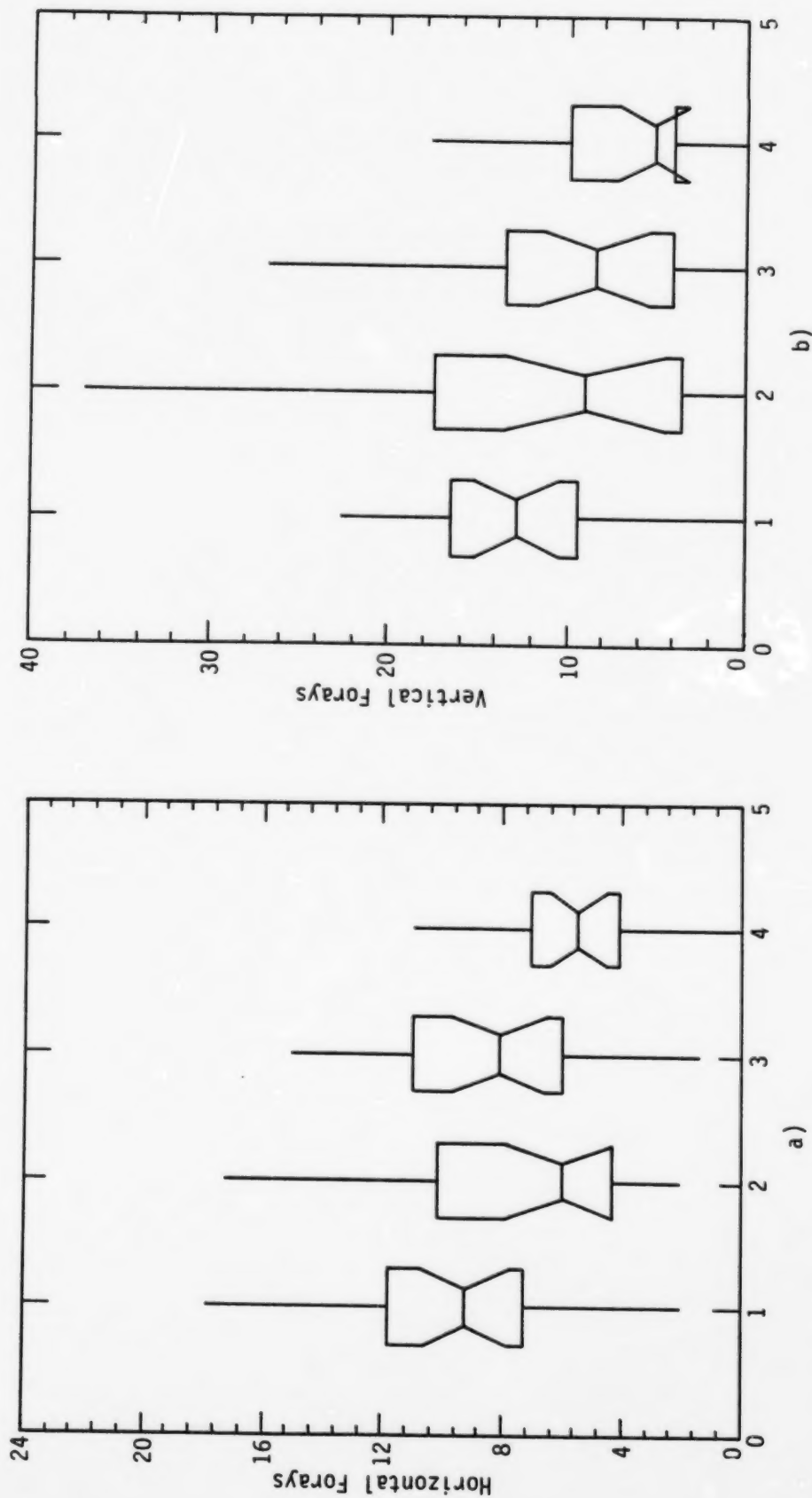


FIGURE 4
MEAN NUMBER OF a) HORIZONTAL AND b) VERTICAL FORAYS
EXHIBITED BY PRAWNS IN THE BARE TANK RELATIVE TO THE FEEDING TIME

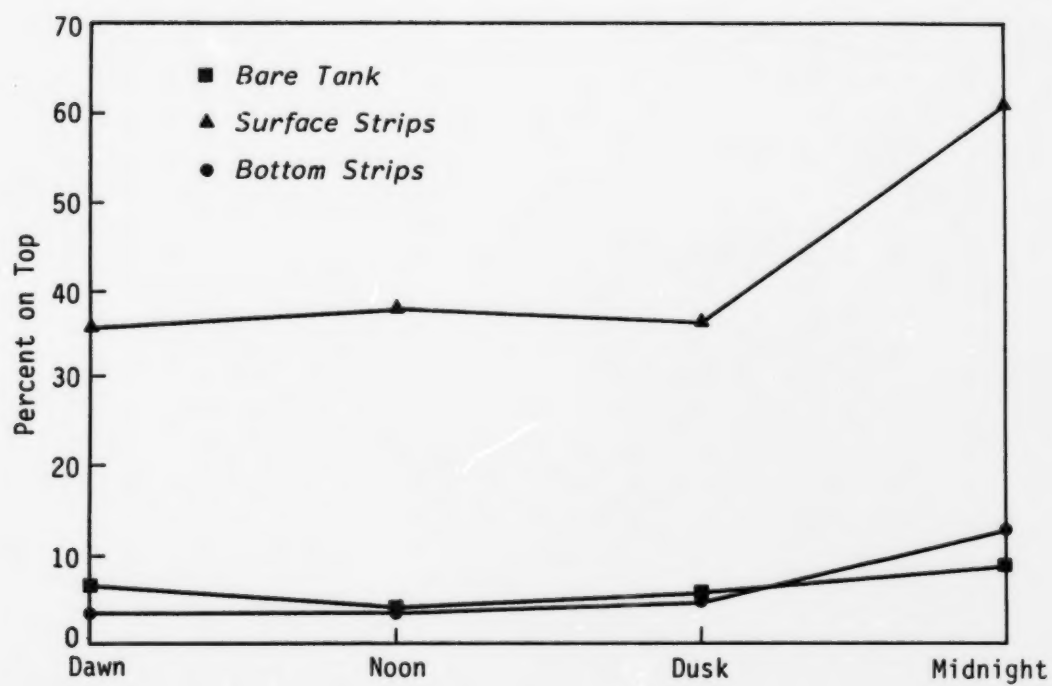


FIGURE 5
MEAN PERCENT OF ANIMALS OCCUPYING THE UPPER HALF
OF THE WATER COLUMN AT DIFFERENT PERIODS OF THE DAY
FOR THE THREE TREATMENTS (n = 192) TREATMENT

A significantly higher number of animals was found in the upper half of the column in the tank containing the surface cover strips during all sampling periods (Figure 2).

Activity of Prawns Over All Treatments

The ANOVA was run to test whether the vertical and horizontal activities differed among treatments and time of day. The results indicated that there was a significant difference among treatment means. The age of the animals and the period of the day were all significant variables (Horizontal Activity Chi-square = 32.01, $P < .0001$; Vertical Activity Chi-square = 24.46, $P < .0001$).

The highest activity, both in terms of vertical and horizontal movement, was found in the clear tank, with no significant difference among the other three treatments (Figure 6). The animals appeared to exhibit a diurnal activity pattern, with highest movement at dawn and noon, and lowest at dusk and midnight, consistent with the results from the bare tank only.

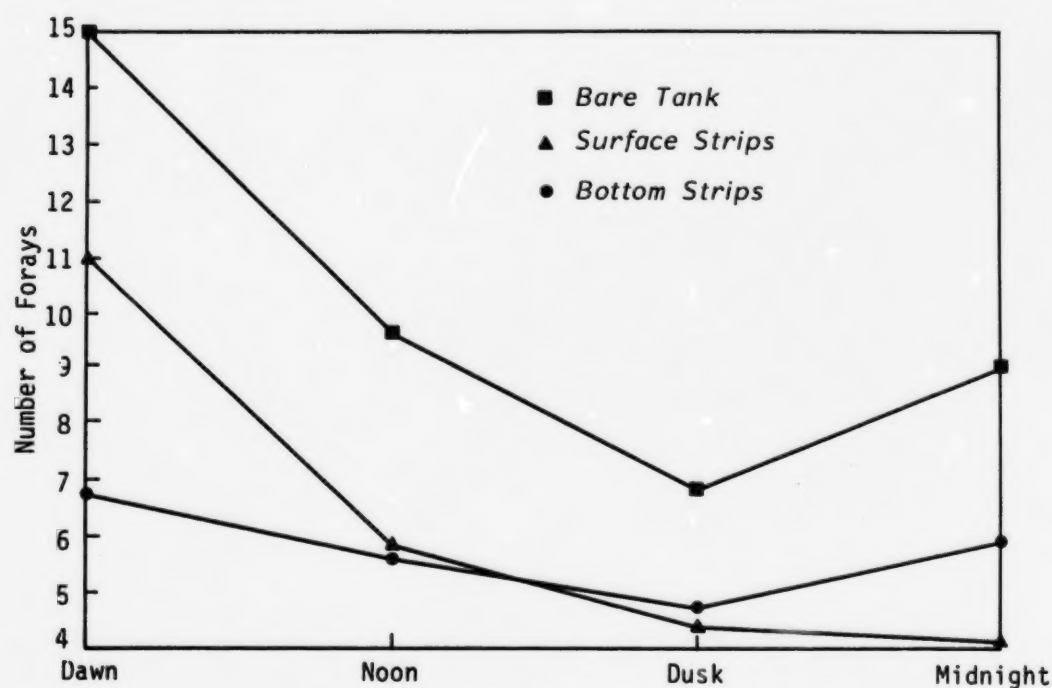
Activity did not change linearly with age, but there appeared to be a higher activity during the third and fourth sampling cycles. The increase in activity, both horizontal and vertical, was observed in all the treatments (Figures 7 and 8).

DISCUSSION

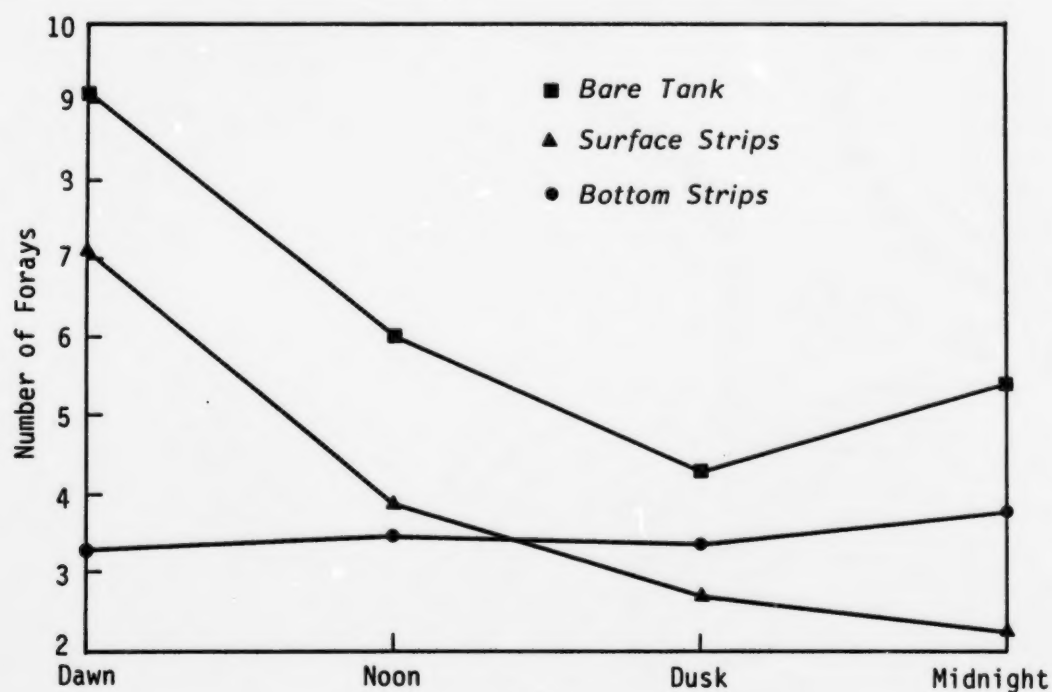
From the analysis of the distribution of the prawns in the flat bottom tank with no cover strips, it became apparent that the animals display a strong preference for the bottom. On the average, less than 10% of the animals used the upper half of the water column, which is consistent with Ling (1969) who described the animals as spending much of their time crawling along the substrate.

The preference for the bottom did not have a strong diurnal periodicity, nor was it influenced by proximity to feeding period. However, the animals' distribution was influenced by the location of the air stone and hose for which they displayed an affinity and tended to cling to the hose. This preference was particularly noticeable when the stone was located in the center of the tank.

Four types of activities were noted during the observations. These were arbitrarily classified as searching (mostly associated with food), swimming, aggressive interactions, and resting. Most of the activities observed consisted of what appeared to be exploratory horizontal movements usually associated with the searching of food. The occurrence of animals in the upper half of the tank was usually associated with 'swimming' activities, that is, individual animals (usually smaller ones) either swimming back and forth near the surface of the tank, or, less frequently, larger individuals 'bobbing' up and down at the ends of the tank. The swimming activity accounted for all of the vertical movement that was observed. On two dates single animals were seen 'resting,' in excess of two



(a)



(b)

FIGURE 6

MEAN NUMBER OF FORAYS PER MINUTE IN (a) HORIZONTAL AND (b) VERTICAL DIRECTIONS AT DIFFERENT PERIODS OF THE DAY FOR THE THREE TREATMENTS (m = 192/TREATMENT)

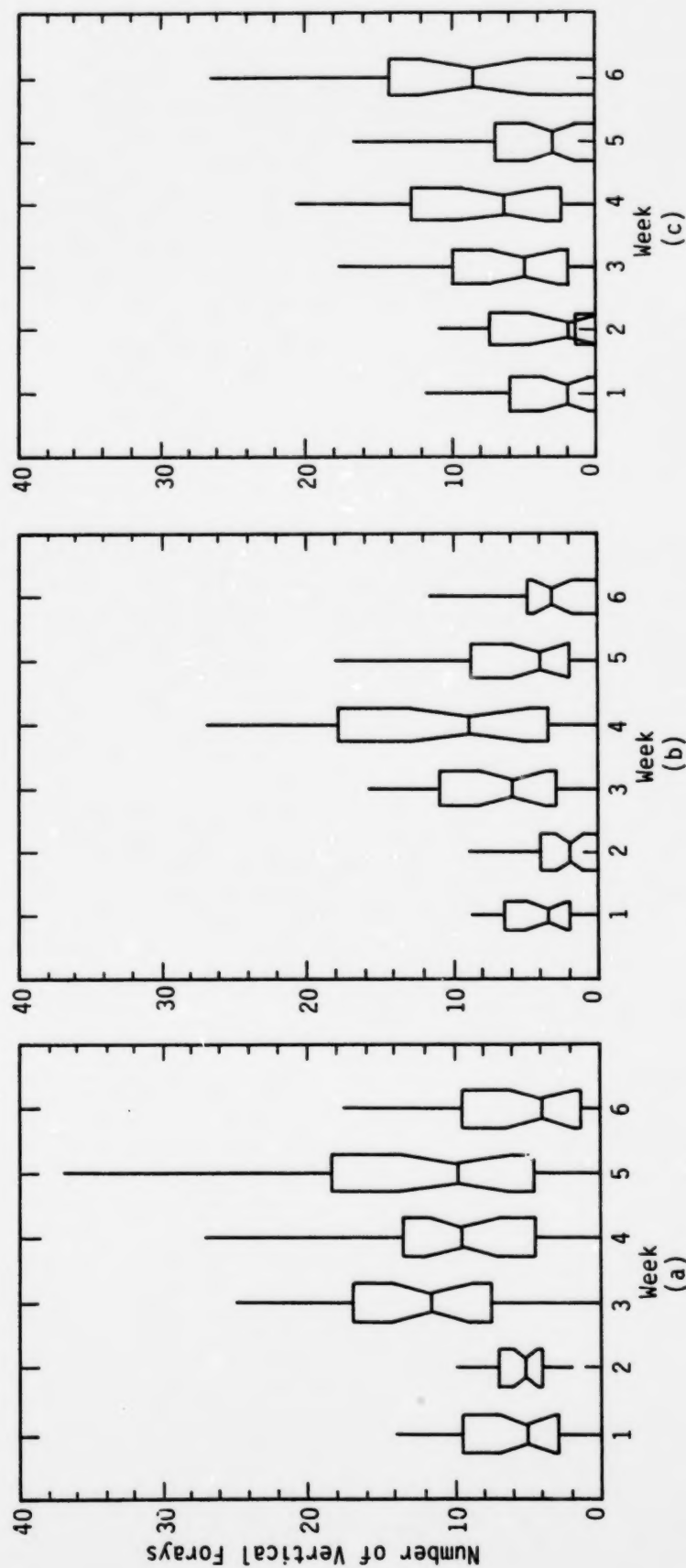


FIGURE 7
 NUMBER OF VERTICAL FORAYS EXHIBITED BY THE PRAWNS
 DURING THE SIX SAMPLING WEEKS IN (a) BARE TANK,
 (b) TANK WITH SURFACE STRIPS AND (c) TANK WITH BOTTOM STRIPS

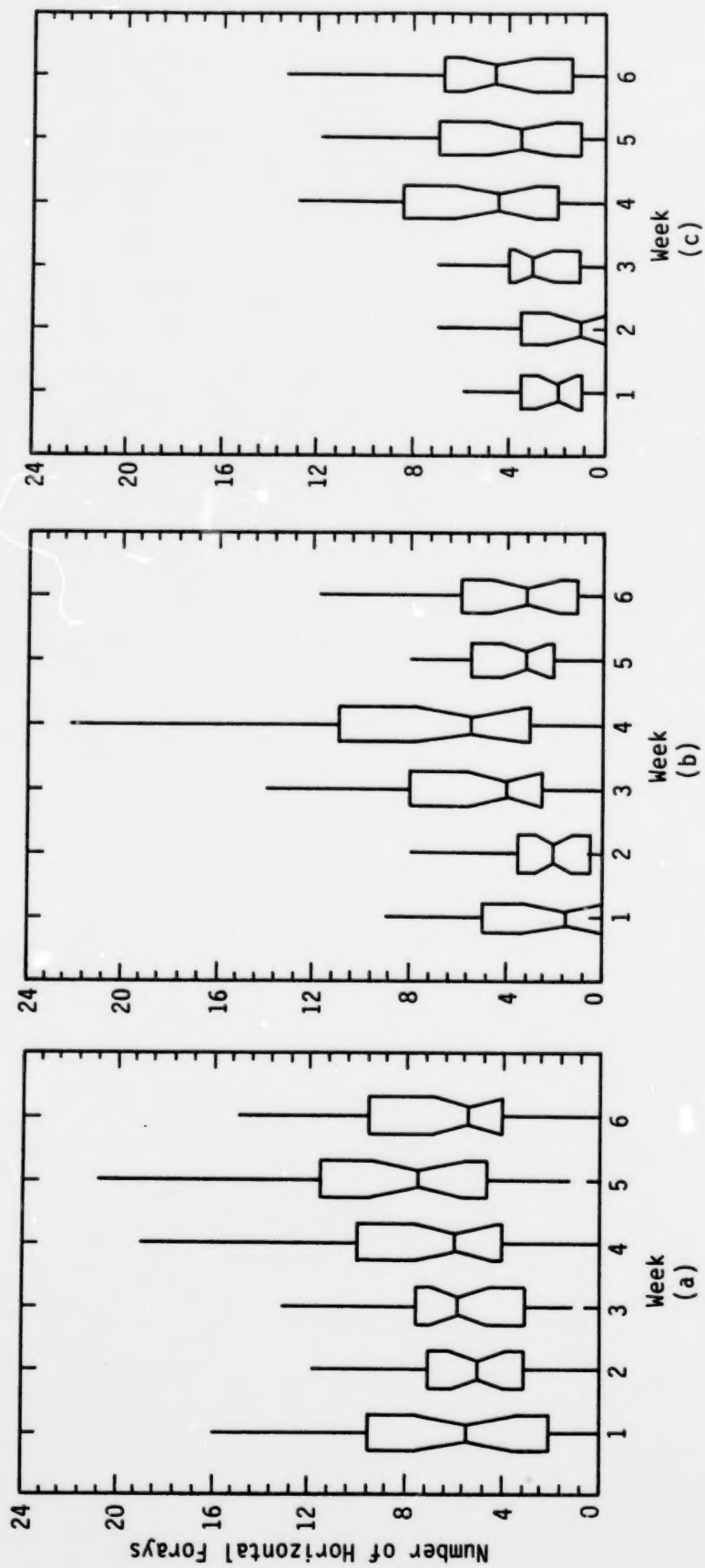


FIGURE 8
 NUMBER OF HORIZONTAL FORAYS EXHIBITED BY THE PRAWNS
 DURING THE SIX SAMPLING WEEKS IN (a) BARE TANK,
 (b) TANK WITH SURFACE STRIPS AND (c) TANK WITH BOTTOM STRIPS

hours, suspended in the water column. This latter type of behaviour seemed rare. Scudder et al (1981) describes the animals as moving from a pelagic to a greater degree of crawling activity following metamorphosis. It would appear that this mode of locomotion becomes even more pronounced in late juveniles than was reported by Scudder, because in this study the ratio of horizontal to vertical forays corrected for distance were approximately 3:1.

The activity pattern observed had a strong diurnal component, with most movement taking place in the early morning, declined by noon, and was lowest in the early evening. Activity levels appeared to increase slightly during the midnight period. Feeding did not alter the pattern but slightly increased the level of activity but not to a significant level.

Nakamura (1975) reported a circadian rhythmicity in the activity of Macrobrachium rosenbergii acclimated to a 12 light/12 dark cycle in dark activity chambers. He described a high level of activity between 18:00 to 06:00 hours and reduced activity in the 06:00 to 18:00 hours, and concluded that the prawns are very active at night and probably do most of their foraging at that time. In this study the observed activities were not consistent with those observed by Nakamura, with the greatest activity having been observed between 08:00 and 10:00 hours, followed by the 11:00 to 13:00 periods, both periods are during daylight, and within the time that Nakamura reported the animals as being quiescent. Likewise the activity levels observed between 23:30 and 01:30 are considerably lower than those reported by Nakamura. These findings are more consistent with Scudder et al (1981) who found a greater activity level during photophase than scotophase, although the increase in nighttime swimming activity which they reported either does not occur in these older animals or was missed in the interval between sampling periods.

The presence of cover had a considerable influence on the distribution and activity of prawns in the tanks. Initially this was seen by the influence of such items as the air hose and stone. The impact of the cover strips on both distribution and activity was even more significant. The animals displayed considerable affinity for the strips, both those suspended from the surface and those sitting on the aquaria bottom. They were observed spending extended periods of time (hours), in the crevices provided by the strips, occasionally defending such strips against intruders. A relative measure of this affinity can be obtained by the proportion of animals that were in the upper half of the tank in the treatment with cover strips suspended from the surface when compared to the bare tank treatment. At the beginning of the experiment as many as 60% of the animals could be induced to utilize the surface strips, while by the end of the six weeks upwards of 40% were still occupying the surface strata, a 6- to 10-fold increase in surface water occupancy over the bare tank.

The level of locomotory activity was highest at all times in the bare bottom aquarium, and lowest in the aquaria containing the covers. The animals in the bare tank were approximately 30% more active than those in tanks containing cover strips. If activity levels reflect agonistic encounters among the males, then it is possible that the presence of cover may enhance survival of individuals.

The use of cover is not new in prawn aquaculture; Smith and Sandifer (1975) used it in tank trials to improve the production of juvenile prawns. Cohen *et al* (1983) and Ra'anani *et al* (1984) concluded that "substrate may improve yields either by reducing growth inhibition..., or by providing hiding places to newly molted and small individuals." In the present study the impact of substrates on survival and yield was not addressed. However, it became clear that a sizable portion of the prawns tested were selecting the artificial substrates which were occupied for extensive periods of time. Individuals tended to occupy the inside of loops leaving them mainly when feeding or disturbed. The cover seemingly mimicked the shelter provided by crevices and plants which juveniles occupy in nature (Raman 1961), and which Peebles (1979) considered a limiting resource.

CONCLUSIONS AND RECOMMENDATIONS

Objectives that must be met for successful intensive aquaculture of prawns involve the ability to grow animals under high density conditions, with a high survival rate, and good rapid growth to marketable size. Problems with existing aquaculture techniques are that animals are typically raised at low densities (ie, relative to water surface area), survival has often been a problem, and a large variation in size is apparent at maturity so that only a fraction of the animals reach a desirable size at any one time. The above problems have been attributed by Ra'anani (1984) to growth inhibition when animals are in close proximity of each other, and absence of hiding places for newly molted individuals.

The results of this study suggest that by the introduction of artificial surfaces the utilization of a volume of water by the prawns can be controlled to a considerable degree. This mechanism may be significant in reducing crowding on the bottom, and equally important, it significantly reduces the amount of movement and hence the number of encounters between animals. Whether broadening the distribution and lowering the number of interactions will improve survival or growth, particularly among rapid growing males, has yet to be determined.

Questions related to cover that still need to be addressed in order to recommend a sound culture strategy are:

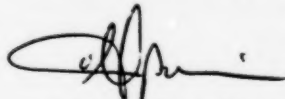
1. To what degree does the manipulation of the prawn distribution impact growth and survival?

2. Can animals nearing maturity be manipulated to the same extent as juveniles?
3. Since much of the size variation seen in maturing individuals has been attributed to inhibition by the faster growing males of smaller males, tests to see whether the inhibition can be reduced by eliminating the limitations imposed by lack of shelters should be carried out under varying size mixtures.
4. If the above three studies have encouraging results then the size, shape, numbers, and orientation of shelters which will maximize yield need to be explored.

ACKNOWLEDGEMENTS

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Approved by:



O.A. Kupcis
Manager
Chemical Research Department

Prepared by:



G.L. Vascotto
Senior Research Scientist
Chemical Research Department

GLV:rv

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